



RESEARCH DEPARTMENT

**405-LINE AND 625-LINE TELEVISION PICTURES:
THE RELATIVE IMPAIRMENT PRODUCED BY RANDOM NOISE**

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**THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION**

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405-LINE AND 625-LINE TELEVISION PICTURES: THE RELATIVE IMPAIRMENT PRODUCED BY RANDOM NOISE

SUMMARY

Subjective assessments have been made, for 405-line and 625-line television pictures, of the impairment produced by addition of random noise to the video signal. It has been found that, for equal impairment, the signal-to-noise ratio must be about 2 dB better for a 405-line picture than for a 625-line picture.

1. INTRODUCTION

In view of the forthcoming adoption of the 625-line standard in this country it is of importance to know the extent to which the change of standard will affect the signal-to-noise ratio corresponding to a given degree of subjective impairment. No previous measurements of the visibility of random noise appear to have been made with the specific object of comparing the visibility for these two standards. An investigation covering both standards has been carried out,¹ but was primarily concerned with establishing the nature of the statistical relationship between objective noise level and subjective impairment, and the results were not thought to give an accurate estimate of the difference in question. During the 1957-8 field trials, pictures were transmitted on both line standards, and their relative tolerance to noise may be estimated from Fig. 93 (p. 119) of Reference 2. It is not possible to draw firm conclusions from this data, however, because of fortuitous differences between the two transmissions, and considerable statistical spread in the results. A series of tests has, therefore, been carried out, using a multi-standard scanner/monitor combination: this allows the standard to be changed instantly and avoids differences between the displays on the two standards.

2. EXPERIMENTAL PROCEDURE

Observers, who were tested singly, sat in front of a 21 in (53cm) monitor at a distance of four times the picture height. A high-quality slide scanner generated a picture (a girl, seated in a studio setting), which was displayed at a peak luminance of 15 ft-L (160 asb). The ambient lighting level was sufficiently low (<0.1 ft-L (1.1 asb) at the tube face) to ensure that the contrast range, which approached 100:1, was limited by flare within the picture tube. The monitor was supplied with separate noise-free synchronizing pulses.

A known level of random noise could be added to the video signal (whose intrinsic noise level was imperceptible) by adjusting an attenuator. Measurements were made both for noise having a uniform spectrum over the video band, which will be

referred to as "flat" noise, and for so-called "triangular" noise, which is obtained when flat noise is passed through a circuit having a voltage gain proportional to frequency. The schematic arrangement and the method of calibration are described in the Appendix. The noisy video signal was bandwidth limited by means of one or other of two low-pass filters, according to the line standard in use; the filters were of identical design, and had cut-off frequencies of 3.2 Mc/s and 5.33 Mc/s* respectively.

In the first set of experiments, which was confined to flat noise, the standard alternated between 405 and 625 lines, a change being made every 10 seconds. The noise level of the 405-line display was set to a known level by means of an attenuator controlled by the experimenter; the noise level of the 625-line display was determined by means of a different attenuator, controlled by the observer, who was asked to adjust it until the noise was equally visible on both standards. When, after a number of cycles of the two standards, the observer considered that he had matched the visibility of noise on the two standards, the reading of his attenuator was recorded; he was also asked to grade the impairment produced by the noise, on a six-point scale.** The test was then repeated with a different noise level. After four observers had been tested in this way, and it had been found that they were achieving consistent results, an alternative procedure was adopted in order to discover whether the results depended upon the precise form of the comparison. The observer was shown a random sequence of different signal-to-noise ratios on one of the standards, and asked to grade them on the six-point scale. The same ratios were then presented, in a different sequence, on the other standard, and the grading again recorded.

It was found that this second method gave results completely consistent with those obtained by the first method. As it allowed the tests to be carried out much more quickly, it was adopted for the remainder of the experiment, which consisted of repeating the test with different observers and for triangular noise. For the tests involving flat noise twenty-two observers were used, comprising fourteen television engineers, three engineers from other parts of Research Department, and five non-technical personnel; for the tests involving triangular noise fourteen of these observers were used, comprising ten television engineers, two other engineers, and two non-technical personnel.

3. RESULTS

The results of the tests are shown in Fig. 1 in which, for each of the four experimental conditions, the mean subjective grade is plotted against the ratio, in dB,

*The cut-off frequency of 5.33 Mc/s corresponds to the 5 Mc/s nominal video-frequency limit of the "Gerber" C.C.I.R. standard. No filter was available with a cut-off frequency corresponding to the 5.5 Mc/s limit of the proposed U.K. standard, and correction of the results to this standard is discussed in Section 4.

**The scale used was:-

GRADE	DEGREE OF IMPAIRMENT
1	Imperceptible
2	Just perceptible
3	Definitely perceptible but not disturbing
4	Somewhat objectionable
5	Definitely objectionable
6	Unusable

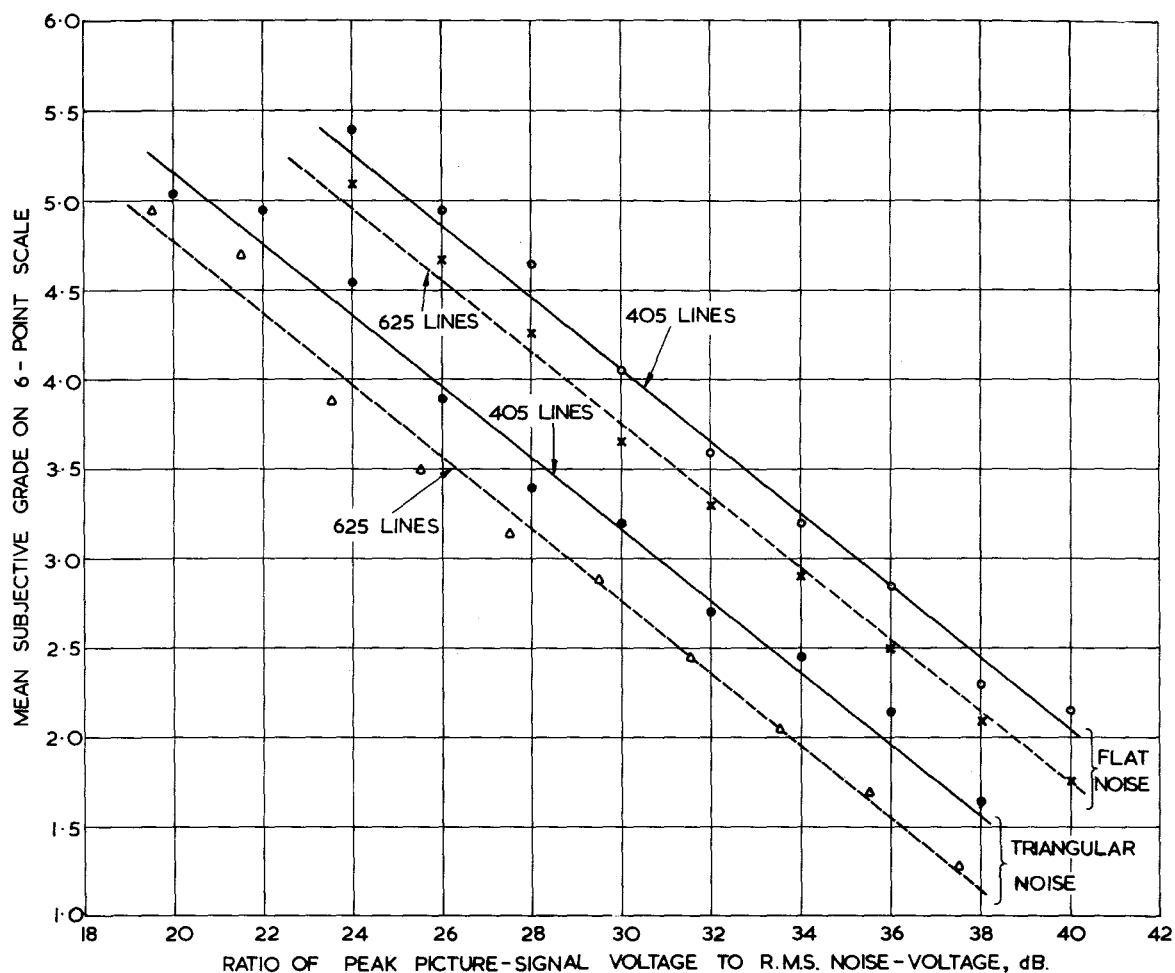


Fig. 1 - Mean subjective grade as a function of signal-to-noise ratio

- 405 lines } flat noise
- × 625 lines } flat noise
- 405 lines } triangular noise
- ▲ 625 lines } triangular noise

between peak picture-signal voltage (i.e. black-to-white) and r.m.s. noise-voltage. It will be seen that the plotted points can be reasonably well represented by four parallel straight lines, having a slope of one subjective grade for each change of 5 dB in the signal-to-noise ratio. For flat noise the subjects' tolerance to noise was 1.5 dB (≈ 0.3 subjective grade) greater for 625 lines than for 405 lines, and for triangular noise, 2.0 dB (≈ 0.4 subjective grade) greater. Triangular noise is 5.0 dB (≈ 1.0 subjective grade) less visible than flat noise on a 625-line display and 4.5 dB (≈ 0.9 subjective grade) less visible on a 405-line display. The signal-to-noise ratios corresponding to a mean grade of 3.5 (which is sometimes taken as defining a "just tolerable" level of impairment) are, to the nearest 0.5 dB:

405 lines, flat noise	32.5 dB
405 lines, triangular noise	28 dB
625 lines, flat noise	31 dB
625 lines, triangular noise	26 dB

4. DISCUSSION OF RESULTS

The experimental result that changing from 405-line to 625-line scanning renders television pictures less susceptible to noise is qualitatively consistent with two well-known aspects of visual perception.

If a constant viewing distance is assumed, use of a greater number of lines results in less effective resolution of individual lines by the observer's eye. As a result of this tendency for neighbouring lines to merge, their uncorrelated noise fluctuations tend to be summed on an r.m.s. basis, whereas their contributions to the picture are, except for fine vertical detail, summed arithmetically; thus an increase of apparent signal-to-noise ratio may be expected to accompany the use of more scanning lines.

However, because adjacent lines of an interlaced picture are scanned during alternate field periods, the extent to which subjective noisiness is reduced in this way depends also upon how effectively the two interlaced rasters are fused, as a result of persistence of vision. Here again the 625-line standard may be expected to have an advantage, because fusion of alternately presented objects is known to become more effective as their angular separation decreases.

The linear relationship between the mean subjective grade and the signal-to-noise ratio may be interpreted as an instance of Weber's Law,* in which the sensation is that of subjective impairment, and its threshold increment a change of one grade. As was stated earlier, the experiments were carried out for a 625-line display having the 5 Mc/s bandwidth of the "Gerber" C.C.I.R. standard; in order to apply the results to the 625-line standard proposed for use in the U.K., which has a nominal bandwidth of 5.5 Mc/s, it is necessary to estimate the effect of increasing the bandwidth. Experiments reported by Mertz³ have shown that increasing the bandwidth of flat noise, without changing the noise power per unit bandwidth, does not change the subjective visibility; this implies that the resultant increase of r.m.s. noise is exactly offset by the finer horizontal structure of the noise. When, therefore, the bandwidth is increased in a ratio $F:1$, and a constant r.m.s. noise is maintained, the visibility decreases by $(10 \log_{10} F)$ dB. When the bandwidth of flat noise is increased from 5 Mc/s to 5.5 Mc/s, therefore, the objective signal-to-noise ratio must be worsened by $10 \log_{10} 1.1 = 0.4$ dB, in order to maintain constant visibility. This result will also be assumed to apply to triangular noise. This involves the reasonable assumption that refinement of the horizontal structure produces the same decrease of visibility for a given r.m.s. noise whether the spectrum of the noise is flat or triangular.

The advantage, relative to the 405-line standard, to be expected from the adoption of a 625-line standard having a nominal video bandwidth of 5.5 Mc/s is thus about 2 dB for flat noise and 2.5 for triangular noise.

It should be noted that although 625-line pictures exhibit greater tolerance to a given objective noise level, the greater bandwidth of a 625-line system will in fact give rise to an increased objective noise level. The substantially flat noise

* Weber's law may be stated thus: for all intensities of stimulus, a threshold increment of sensation is produced by the same increment of the logarithm of the stimulus.

generated by an a.m. receiver, for example, will increase by 2.6 dB for a given amplitude of received carrier, if the bandwidth is increased from 3 Mc/s to 5.5 Mc/s; thus under fringe-area conditions, where the receiver is the main source of noise, changing to 625 lines would produce a nett deterioration of less than 1 dB (≈ 0.2 subjective grade). However, if the predominant source of noise had a spectrum that rose with increasing video frequency, then a greater degree of deterioration would be expected to result from increasing the bandwidth. For example in the case of an f.m. receiver, such as is used in television links, the noise has a triangular spectral distribution; increasing the bandwidth from 3 Mc/s to 5.5 Mc/s would therefore result in a deterioration of 7.9 dB in the signal-to-noise ratio; if this were the predominant source of noise, the subjective visibility would worsen by over 5 dB (≈ 1 subjective grade).

5. CONCLUSIONS

It has been found that the signal-to-noise ratio of a 625-line television picture can be about 2 dB lower than that of a 405-line picture for a given subjective impairment, a result which is qualitatively consistent with well-known aspects of visual perception. Consequently, when the predominant source of noise in a television chain produces noise having a uniform spectrum, the additional noise introduced, because of increased bandwidth, in changing from 405 lines to 625 lines, will produce a negligible subjective deterioration. When the predominant noise has a rising spectrum, however, considerable deterioration will result from the change of standard.

6. REFERENCES

1. Weaver, L.E., "Subjective Impairment of Television Pictures; Effect of Signal-to-Random Noise Ratio", *Electronic and Radio Engineer*, Vol. 36, No. 5, p. 170, May 1959.
2. "Television Field Trials of 405-line and 625-line Systems in the U.H.F. and V.H.F. Bands 1957-8", B.B.C. Publication, May 1960.
3. Mertz, P., "Perception of Television Random Noise", *J.S.M.P.T.E.*, Vol. 54, No. 1, p. 8, January 1950.

APPENDIX

The experimental arrangements are shown in Fig. 2, which refers to flat noise. For the tests involving triangular noise, a constant-impedance equalizer, having a voltage gain proportional to frequency up to 6 Mc/s, was connected to the output of the noise generator, and was followed by an amplifier, which restored the noise to a suitable level. The alternative attenuators in the noise path were used only in the preliminary tests, in which observers adjusted the noise level on one standard; in the main tests, only one attenuator was used. Calibration was carried out as follows:

- (1) The peak value of the picture-signal voltage at the input to the picture monitor was measured on the waveform monitor, the noise attenuator being set to a very high value (90 dB).
- (2) A sine-wave (frequency = 0.5 Mc/s) whose amplitude bore a convenient relationship to the peak picture-signal voltage was substituted for the video signal, by means of the switch "A", and the gain of the thermocouple amplifier was adjusted to produce a standard meter-reading.
- (3) The switch "A" was returned to its normal position, the 3 Mc/s filter selected, and a 75 Ω resistor substituted for the output of the scanner. The attenuator in the noise path was then adjusted until the thermocouple

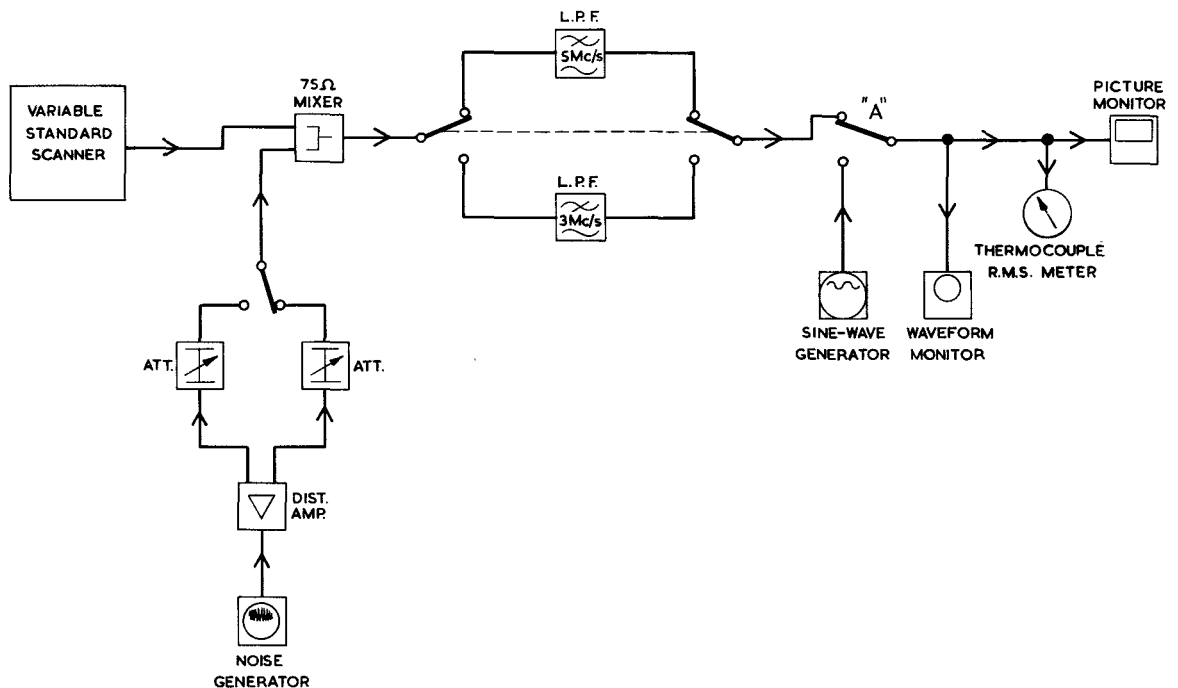


Fig. 2 - Schematic diagram of experimental arrangement

again produced the standard meter reading, and the value of the attenuation noted. A constant relating the number of decibels in the attenuator to the signal-to-noise ratio could thus be calculated very simply.

- (4) The processes described in (3) were repeated for the 5 Mc/s filter.
- (5) The output of the scanner was re-connected. The theoretical increase of attenuation necessary to compensate for the change from the 3 Mc/s filter to the 5 Mc/s filter is 2.2 dB. In practice a value of 1.8 dB was found. A value of 2.0 dB was therefore used in computing the relative signal-to-noise ratios for the two standards. The frequency response of the thermocouple meter was uniform to within ± 0.25 dB up to 5 Mc/s.